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**METHOD AND APPARATUS FOR  
CANCELLING INTERFERENCE IN SIGNALS  
HAVING UNDERGONE MULTIPATH**

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**Related Invention**

Reference is made to U.S. Patent Application No. 08/253,454  
10 filed June 3, 1994, "Method and Apparatus for Subscriber Power  
Level Adjustment in a Communication System" in behalf of  
Kotzin et al., filed on the same date herewith, containing related  
subject matter and assigned to the assignee of the present  
invention.

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**Field of the Invention**

The present invention generally relates to cancelling  
20 interference in signals, and more particularly to a method and  
apparatus for cancelling interference in signals having undergone  
multipath.

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**Background of the Invention**

In a communication system such as a direct sequence  
spread-spectrum code division multiplex system (DS-CDMA), the  
uplink signal (the signal from a subscriber to a base-station)  
30 comprises a multiplicity of overlapping coded signals from  
individual subscribers. Each of these signals occupies the same  
radio frequency (RF) carrier simultaneously and are  
distinguishable only by their specific encoding. The uplink signal  
is received at a base-station receiver as a composite received signal.

In conventional DS-CDMA systems, the base-station receiver decodes each subscriber separately by applying each respective subscribers' code to the composite received signal. Each individual subscriber's signal is thereby "despread" from the composite received signal. Due to the nature of the family of codes utilized, the other subscriber's signals remain in a spread form and act only to degrade the recovered signal as uncorrelated interference. This allows the decoding of user data bits for a particular subscriber.

Prior art techniques of interference cancellation are known which act to reduce even the uncorrelated interference. This permits an increase in the sensitivity and or capacity of the multi-user system. The most common technique is to synthesize a replica of a particular subscriber's received signal, after it has been properly decoded, and utilize the synthesized replica to cancel interference (by subtraction) in the received signal. The synthesized replica may be of the spread or despread forms of the particular subscriber's received signal.

In a land mobile environment, received signals from subscribers undergo multipath. In other words, a transmitted signal undergoes multiple reflections before it is received at a base-station, and these reflections cause "echoes" of the transmitted signal to be simultaneously received. These echoes are generally of different amplitudes and different delays, and therefore the signal received from each subscriber in actuality consists of a multiplicity of signals (the actual signal and its echoes), each having a different delay and amplitude. It is this multipath that provides a significant contribution to the interference that the received signal experiences.

Because of the multipath, interference cancellation techniques are deficient in that synthesis of the replica of a particular subscriber's received signal since it does not take into consideration the multipath nature (i.e., the echoes) of the

received signal. Therefore, a need exists for improved interference cancellation which accounts for multipath of the received signals.

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### Brief Description of the Drawings

FIG. 1 generally depicts, in block diagram form, a receiver unit which may beneficially implement interference cancellation in accordance with the invention.

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FIG. 2 generally depicts, in block diagram form, a cascade of receiver units which implement interference cancellation in accordance with the invention.

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### Detailed Description of a Preferred Embodiment

A receiver unit cancels interference in a composite received signal by synthesizing a replica of the composite received signal which accounts for multipath effects (echoes) of the composite received signal. The receiver unit is comprised of a RAKE receiver, which identifies correlation peaks of the various multipath echoes. The correlation peaks are characterized by time delays and respective amplitudes and phases of the various multipath echoes. By generating a cancellation signal which utilizes the correlation peaks of each multipath echo, a signal more representative of the actual composite received signal is utilized to improve the degree of interference cancellation.

To perform interference cancellation in a signal having undergone multipath in accordance with the invention, a receiver receives the signal. In the preferred embodiment, this received signal having undergone multipath is a composite of a group of subscribers who occupy the same RF carrier (i.e., a composite received signal). Next, a cancellation source is generated based on the signal's multipath. In the preferred embodiment, the

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cancellation source is an analog cancellation signal, but one of ordinary skill in the art will appreciate that alternate embodiments may implement a cancellation source in digital form. Finally, that cancellation source is utilized to help cancel  
5 the interference within the composite received signal. Cancellation is effected by summing the analog cancellation signal with the signal having undergone multipath (i.e., the composite received signal).

In U.S. Patent "Method and Apparatus for Cancelling  
10 Spread-Spectrum Noise" by Stilwell, et. al., U.S. Patent 5,235,612, assigned to the assignee of the present invention, and incorporated herein by reference, a spread spectrum noise canceller is described. In one embodiment of the interference canceller, a technique for decoding a single subscriber's signal using the conventional DS-  
15 CDMA despreading operation is provided. By properly decoding a subscriber's signal, it is possible to effectively eliminate this subscriber's signal from the composite received signal. The decoding of a second subscriber's signal with greater accuracy is thereby made possible using the "subsequent" composite received  
20 signal (i.e., after interference cancellation) without the contribution of the first subscriber. This process can be applied iteratively to all user signals.

FIG. 1 generally depicts a receiver unit 121 which may beneficially implement interference cancellation in accordance  
25 with the invention. As depicted in FIG. 1, only a single receiver (for receiving only SUBSCRIBER<sub>1</sub> out of SUBSCRIBER<sub>N</sub>) is depicted for purposes of clarity. Continuing, a composite received signal 102 is comprised of user information (depicted DATA 1, 2, . . . N) for N subscribers. As previously stated, composite received  
30 signal 102 has undergone multipath, and as a result composite received signal 102 is represented by various echoes. Continuing, composite received signal 102 is downconverted by oscillator 116 and input into receiver unit 121. The signal is split for input into delay 126 and RAKE receiver (means for receiving and generating)

122. As is well known in the art, RAKE receiver 122 provides multipath characteristics which arise from the correlation peaks of the various echoes. For a background on utilizing RAKE receivers in communication systems, reference is made to John G. Proakis, 5 *Digital Communications*, Second Edition, U.S.A., 1989 at pages 728-739. Continuing, these multipath characteristics include, but are not limited to, time delays and respective amplitudes and phases between correlation peaks. Consequently, utilizing composite received signal's multipath, RAKE receiver 122 is capable of 10 generating a replica of composite received signal 102, which is utilized as a cancellation source. In the preferred embodiment, the cancellation source is in the form of analog cancellation signal 124. Cancellation source 124 is then summed, via a summing node (means for cancelling) 128, with composite received signal 102 so 15 that any interference contributed by SUBSCRIBER<sub>1</sub> is substantially eliminated. Resulting signal 130 represents composite received signal 102 "clean" of any interference contributed by SUBSCRIBER<sub>1</sub>.

This technique can be advantageously utilized in a cascade 20 of receiver units. FIG. 2 generally depicts a cascade of receiver units 221, 231, 241 which implement interference cancellation in accordance with the invention. The operation of each receiver unit 221, 231, 241 is identical to the description of unit 121 with reference to FIG. 1, except that RAKE receivers 222, 232, 242 are 25 each dedicated to decoding information of particular subscribers SUBSCRIBER<sub>1</sub>, SUBSCRIBER<sub>2</sub>, SUBSCRIBER<sub>N</sub>. As stated previously, resulting signal 230 is input into receiver unit 231 "clean" of any interference contributed by SUBSCRIBER<sub>1</sub>, and so on.

30 A point to make about multipath is that it tends to be relatively slow. Therefore, moderately long term averaging is possible to improve the estimation of the existence of a particular multipath echo. Also, for the downlink, it is possible to estimate multipath of a transmitted signal using the pilot generally

associated with interfering signals. This is typically transmitted at a much higher level and with less modulation.

While the preferred embodiment of a RAKE receiver has been shown, one of ordinary skill in the art will appreciate that other receivers may be suitably adapted for similar implementation. For example, a receiver which utilizes a  
5 maximum likelihood sequence estimation (MLSE) equalizer could be beneficially employed to yield similar results.

While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in  
10 form and details may be made therein without departing from the spirit and scope of the invention.

What we claim is:

**Claims**

1. A method of cancelling interference in a signal having  
undergone multipath, the method comprising the steps of:  
5 receiving the signal having undergone multipath;  
generating a cancellation source based on the signal's  
multipath; and  
utilizing said cancellation source to help cancel said  
10 interference.

2. The method of claim 1 wherein said step of receiving is performed by a RAKE receiver.
3. The method of claim 1 wherein said step of receiving is performed by a receiver incorporating a maximum likelihood sequence estimator (MLSE) equalizer.
4. The method of claim 1 wherein said step of generating a cancellation source further comprises the step of generating a cancellation signal utilizing the signal's multipath.
5. The method of claim 4 wherein said step of utilizing said cancellation source to help cancel said interference further comprises the step of summing said cancellation signal with the signal having undergone multipath.

6. An apparatus for cancelling interference in a signal having undergone multipath, the apparatus comprising:

5 means for receiving the signal having undergone multipath and generating a cancellation source based on the signal's multipath; and

means for cancelling interference in the signal having undergone multipath utilizing the cancellation source.

10 7. The apparatus of claim 6 wherein said means for receiving further comprises a RAKE receiver.

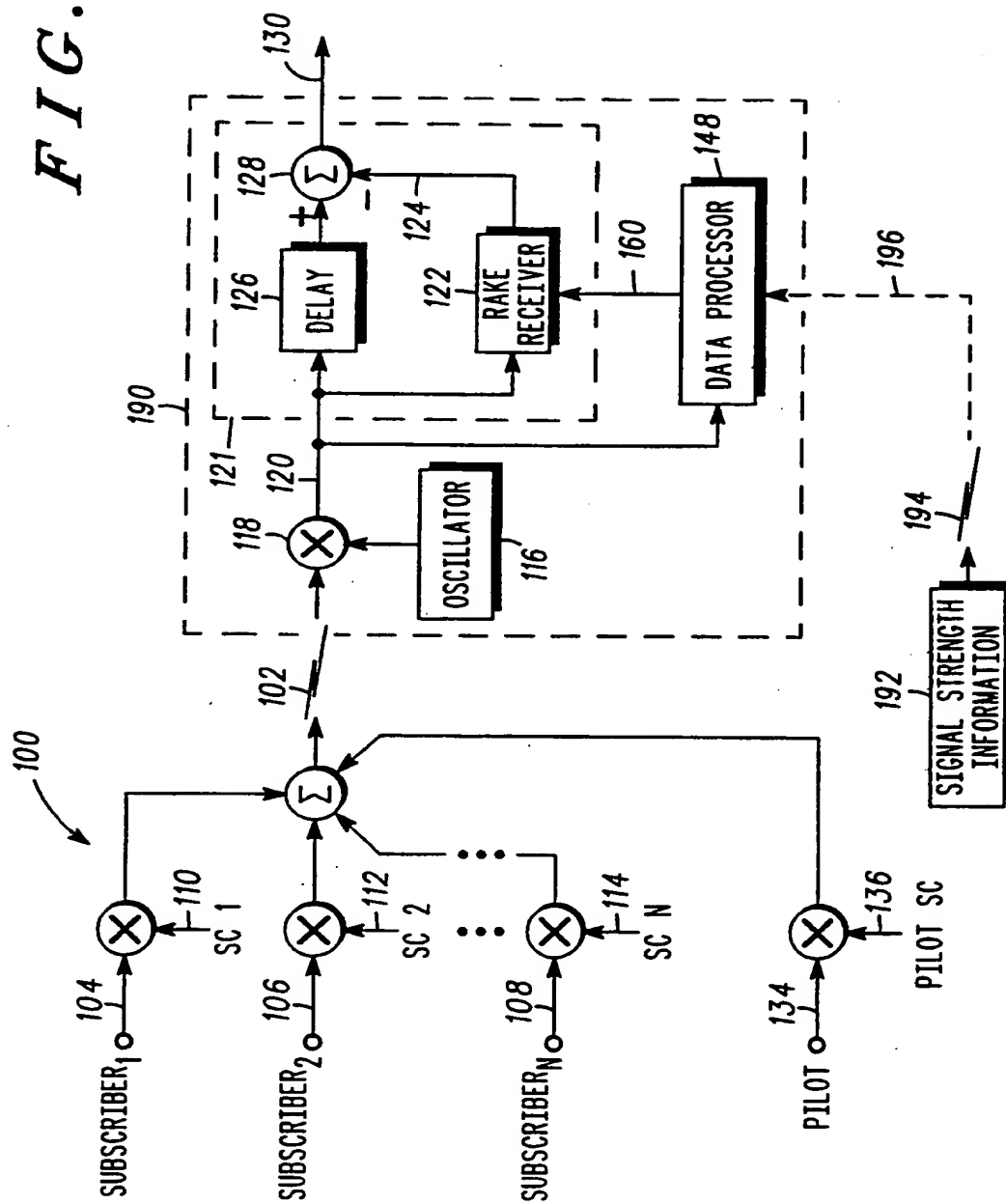
8. The apparatus of claim 6 wherein said means for receiving further comprises a receiver incorporating a maximum likelihood  
15 sequence estimator (MLSE) equalizer.

9. The apparatus of claim 6 wherein said means for generating a cancellation source further comprises means for generating a cancellation signal utilizing the signal's multipath.  
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10. The apparatus of claim 6 wherein said means for cancelling further comprises means for summing said cancellation source with the signal having undergone multipath.

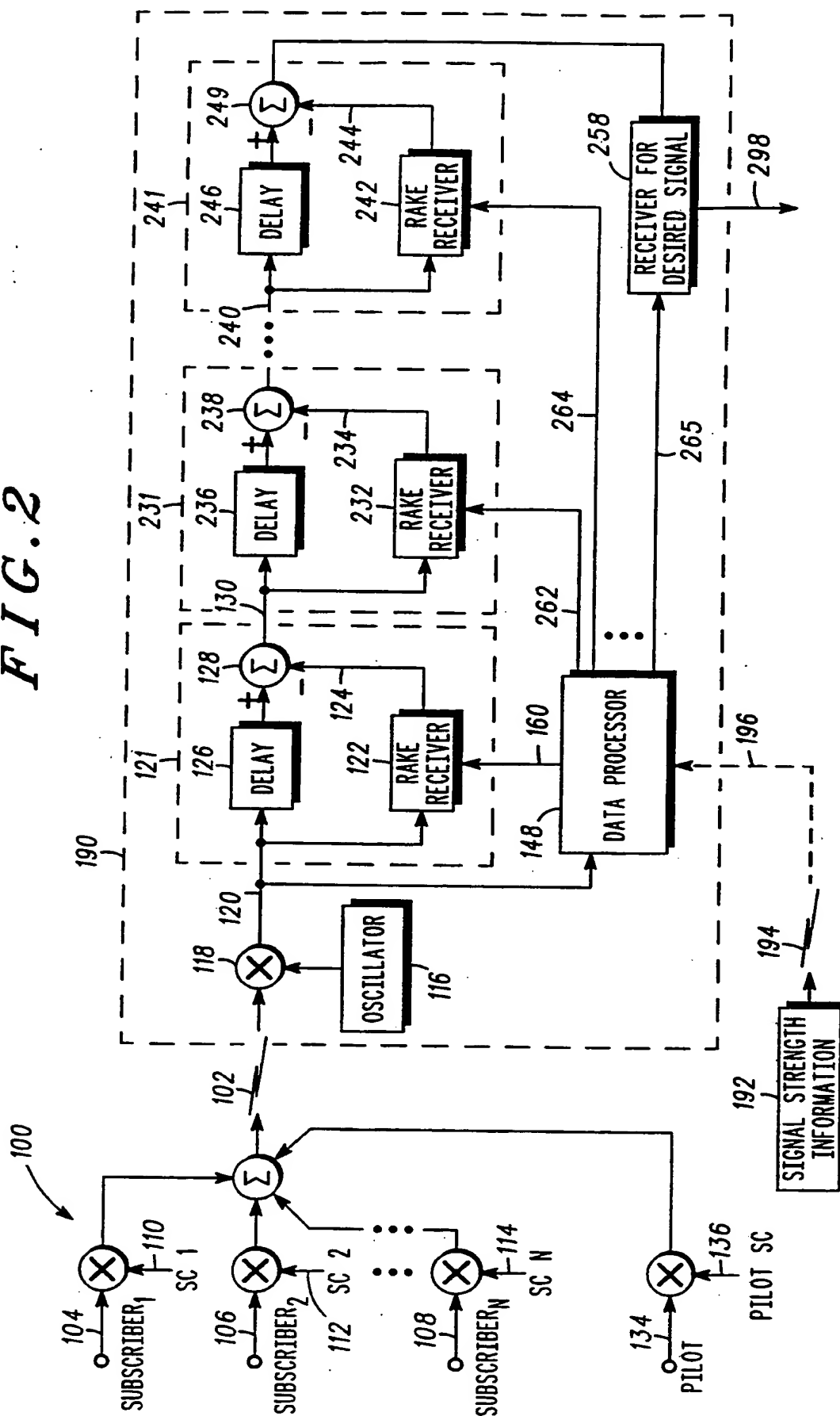
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FIG. 1



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FIG. 2



## INTERNATIONAL SEARCH REPORT

 International application No.  
 PCT/US95/04307

## A. CLASSIFICATION OF SUBJECT MATTER

 IPC(6) : H04B 1/69 =  
 US CL : 375/200

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/200-210, 229-235; 380/34; 455/63, 65, 296, 303

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 2,982,853 (PRICE ET AL) 02 May 1961, see entire document.	1,4,5,6,9, 10
X	US, A, 3,662,108 (FLANAGAN) 09 May 1972, see entire document.	1,4,5,6,9, 10
X	US, A, 4,266,296 (ISHIGAKI) 05 May 1981, see entire document.	1,4,5,6,9, 10
X	US, A, 4,349,915 (COSTAS) 14 September 1982, see entire document.	1,4,5,6,9, 10
X	US, A, 4,457,007 (GUTLEBER) 26 June 1984, see entire document.	1,4,5,6,9, 10
X	US, A, 4,519,084 (LANGSETH) 21 May 1985, see entire document.	1,4,5,6,9, 10

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Date of the actual completion of the international search 09 MAY 1995	Date of mailing of the international search report 14 JUL 1995
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## INTERNATIONAL SEARCH REPORT

International application No.  
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## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,590,615 (OHTAKI ET AL) 20 May 1986, see entire document.	1,4,5,6,9, 10
X	US, A, 4,669,091 (NOSSEN) 26 May 1987, see entire document.	1,4,5,6,9, 10
X	US, A, 4,672,638 (TAGUCHI ET AL) 09 June 1987, see entire document.	1,4,5,6,9, 10
X	US, A, 4,873,683 (BORTH ET AL) 10 October 1989, see entire document.	1,4,5,6,9, 10

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